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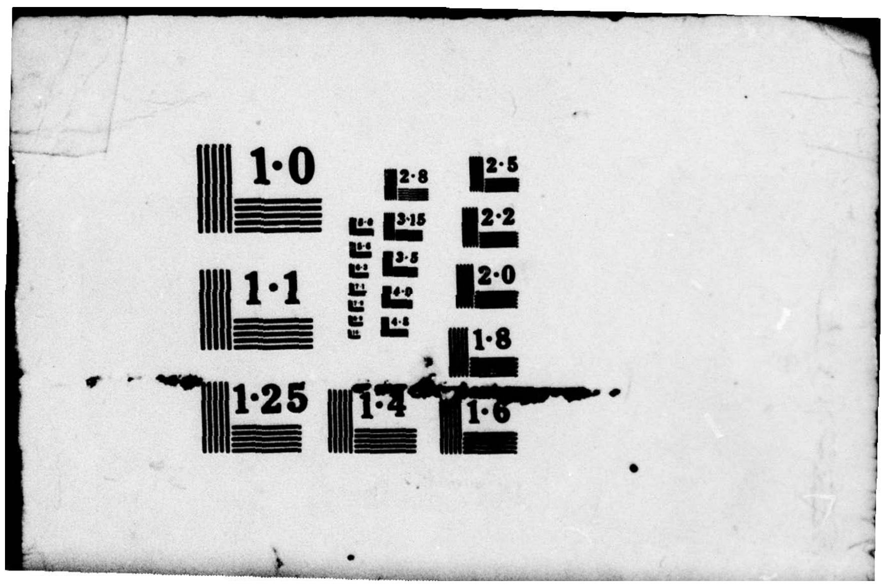
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by

(10) R. K. Huber, L. J. Low and J. G. Taylor

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Following a brief discussion on the need for and the contents of a theory of combat, a conceptual approach to approximate such a theory is proposed and some major previous attempts to establish combat laws are reviewed.

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Introduction

This report documents the authors' contributions to the design and conduct of the "Theory of Combat" workshop sponsored jointly by the Defense Nuclear Agency and the Naval Postgraduate School and held at the Naval Postgraduate School, Monterey, California, 10-11 July 1979.

The purpose of the workshop was to

(1) define what a theory of combat entails;

(2) whether and why such a theory is needed;

(3) whether the development of a theory of combat is feasible;

(4) how one might proceed in developing a theory of combat.

While the results of the conference will be published in detail by the Defense Nuclear Agency, it is the perception of the authors of this report that the workshop rather unanimously agreed that a theory of combat is needed and its development is feasible.

The majority of the workshop participants felt that the need to improve the theoretical basis of defense planning support (e.g. related to operations planning, weapon system design and selection, force structure planning, force sizing, operational concepts and tactics, defense concepts) appeared to be the principal reason why a theory of combat should be developed. Additionally, they felt that the desire to better explain and understand the phenomenon of combat was an important secondary justification. The question as to what a theory of combat is to

cover beyond the phenomenon associated with the mutual infliction of casualties in battle needs to be further debated. With respect to defense planning issues it appears necessary to extend the scope of the theory to perhaps also cover some politico-military paraphernalia of combat, but to limit it as to exclude the (mere) exchange of strikes in a militarily static environment (e.g. strategic nuclear exchanges). There appeared to be two development approaches forwarded at the workshop, a "descriptive" historical approach and a "normative" systems analysis approach. While the historical approach aims at deriving combat laws directly from a study of combat histories, the systems analysis approach is based on combat simulations providing "histories" for the various combat process hypotheses in historical settings.

The research underlying papers presented at the appendices has been supported in part by the Office of Naval Research through the Foundation Research Program (Taylor) and in part by the Scientific Affairs Division of NATO through the NATO Research Grants Programme (Huber). The authors also wish to express their appreciation and thanks to Lt. Col. Richard S. Miller, USA, and to Professor Michael G. Sovereign for their valuable contributions and discussions throughout the genesis of the papers.

APPENDIX A: TOWARDS A THEORY OF COMBAT

by

R. K. Huber, L. J. Low, J. G. Taylor

The Need for a Theory of Combat

A rather persistent observation that surfaces periodically from the analysis community involved with the development and use of combat models is that of the need for a theory of combat ([1]-[3]). Today, modeling efforts are usually centered around specific problems and pending program appropriations related to weapon system and force structure planning. The proliferation of model developments on land/air combat is ample proof, not only to an almost exclusively decision-oriented approach to combat modeling (see Huber [2]), but also to the fact that each model tends to reflect the particular analysts' and/or users' perceptions on combat elements and processes. Thus, models appear to be based primarily on (frequently even diverging) hypotheses rather than on empirically tested theories. In a recent (September 1977) workshop for theater-level gaming and analysis [4], the issue of a requirement for a "theory of combat," or "laws of war," or for "insights into the phenomena of war," was expressed many times.

It is believed that an intellectual, scientific endeavor of this type, albeit extraordinarily difficult, is sorely needed to link the model abstractions of combat to what happens, in reality, on the battlefield. The need for a viable theory of combat becomes increasingly manifest as the changes in the strategic balance, the emergence of new weapons and information technologies and, last but not least, the alarming increase in systems

cost will eventually require a series of vital decisions on defense concepts, force structures, and weapon developments that may tax our present methods of analysis beyond all credibility. Thus, we must strive for some capability to "benchmark" our analytical techniques against reality.

It is for these reasons that the following preliminary thoughts are presented as a frame of reference for subsequent discussion during the workshop in July. From these discussions, hopefully, will emerge a viable research approach to a theory of combat.

Definition of a Theory of Combat

A theory of combat may be defined as the embodiment of a set of laws governing military combat. In particular, it would

(1) discern patterns in the interactions and relationships among the major elements of combat[1] that operate through a set of distinct combat processes;[2]

(2) identify particular patterns of interactions and relationships which consistently shape or determine the outcome of combat (defined in some manner);

(3) express the patterns so identified in quantitative terms, i.e., as functional relationships between sets of independent and dependent variables.

---

[1] combat circumstances, operating environment, human combatants (characteristics and behavior), hardware and software implements of warfare.

[2] attrition, movement, command, control, communications and intelligence (C^3I), combat support.

Elements of a Theory of Combat

Any scientific theory of a dynamic system must involve the following elements:

(a) independent variables (inputs),

(b) dependent variables (outputs,

(c) system processes (relating inputs to outputs over time).

Applying such a conceptual framework to military combat at the tactical level, we envision the elements of a theory of combat as consisting of the following:

(1) independent variables of combat (inputs to combat),

(2) dependent variables of combat (mission-oriented outputs),

(3) combat processes (relating combat inputs to outputs over time).

These three basic elements of a theory of combat will now be elaborated upon in the next three sections.

Furthermore, the set of input variables is very large (combat is a very complex process), and, therefore, another important element of a theory of combat is the classification and organization of the set of input variables into more manageable subsets (cf., the work of COL T. N. Dupuy (USA, ret.) of HERO [5]). Moreover, the system modeler needs to know which of the input variables are the significant variables in the sense that inputs can be "adequately" related to outputs. Finally, although the above basic set of elements is of general applicability, its realization in specific instances is unquestionably quite variable and a systematic examination is required.

Dependent Variables (Outputs)

Ultimately, a viable theory of combat is to provide defense analysts and planners a better perspective on the contribution of alternative force designs and operational concepts in order to attain the military objectives set forth by the national objectives. Thereby, we consider the military objectives to define the (ultimate) military mission in the context of a theater (e.g., for NATO, the mission to preserve her territorial integrity). Thus, the theory of combat relates the independent variables or inputs to the (degree or probability of) mission accomplishment, through a hierarchy of objectives and dependent variables as measures of their attainment at each level of combat (engagement → encounter → battle → campaign → war). At each level, the upper level sets the objectives and the scenarios, the lower level provides the inputs (Bode [6], Huber [2]).

Independent Variables (Inputs)

The independent variables upon which the outcome of combat depends may be grouped into essentially six categories:

(1) mission;

(2) human combatant characteristics and behavior;

(3) material resources such as weapons, vehicles, supplies, etc.;

(4) organization and structure;

(5) doctrine and operational concepts;

(6) the physical environment (e.g., weather, terrain, urbanization, transportation network, etc.) prevailing in the potential theater(s) of operation.

In due course of the development of a theory, the variables in each of these categories have to be identified and their relevance (to the outputs) must be established at each combat level. In addition, methods of their measurement have to be developed.

Combat Processes

The process of military combat takes the inputs to combat and converts them into outputs. However, this overall combat process is extremely complicated, and consequently it seems appropriate to factor this overall process into simpler, more manageable subprocesses. Traditional military thinking of the U.S. Army provides the basis for one such possible factorization of the overall combat process: in the U.S. Army's own words [7], the fundamental role of ground-combat troops is to "shoot, move, and communicate." Hence, one has at least an intuitively appealing basis for proposing the following factorization of the overall combat process:

(1) attrition,

(2) movement,

(3) C^3I (command, control, communications, and intelligence),

(4) support.

We have added the support (logistics) process to the list of processes corresponding to shooting, moving, and communicating, since it functions (essentially independent of the other combat processes) in combat operations to sustain these other combat processes.

Approaches to Developing a Theory of Combat

The basic scientific approach for developing a theory of combat is to use "empirical data" obtained in a systematic fashion through "controlled experiments" to establish the functional relationship between the independent variables (inputs) and the dependent variables (outputs) of combat.

There are essentially three principal approaches to develop functional relationships between the inputs and outputs of military systems:

(1) the historical approach through the study of records of historical combat;[3)]

(2) the judgmental approach based on field experience in combat and/or military exercises;

(3) the operational analysis approach through the use of physical and/or formal models.[4)]

---

3) Although there are many difficulties associated with this approach, it has never been systematically pursued in the past (at least to definitively establish the bounds on its realm of applicability), and, therefore, a well-thought out historical research program should be an essential part of any future effort to develop a theory of combat.

4) Depending on the models used, the operational analysis approach may be further subdivided. It encompasses the entire range from (controlled) field experiments to highly abstract analytical models (see Low [4], Taylor, [8,9], Huber and Wobith [10]). They serve to pursue a program of controlled "simulated-combat" experiments (within the constraints of player-personnel safety) in order to generate quasi-combat data for developing the functional relationship between inputs and outputs. Thereby, one can view not only military organizations as being hierarchical (e.g., company, battalion, brigade, division, corps, army) but also military combat itself (e.g., engagement, battle, campaign, war). The consideration of hierarchical combat models is necessitated by the great inherent complexity of combat. Thus, the classification and organization of variables, data sources, combat situations, etc., appears to be an integral part of the development of a theory of combat.

With respect to the development of a theory of combat, these approaches must be considered as complementary rather than competing. It is necessary to integrate them such, that through their interaction, hypotheses related to military combat may be tested as a prerequisite to the development of a viable theory. To this end, strategies for the development of such integrated approaches shall be identified and assessed to establish priorities for further research and development support.

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APPENDIX B:

IDENTIFICATION OF THE MAJOR FACTORS IN COMBAT

by

L. J. Low

In this paper, we will explore in greater detail those factors identified in our definition of a theory of combat. As a result of this exploration we hope we can better understand certain fundamental relationships among these factors. We will attempt to fashion in a heuristic manner a picture of the final outcome, formed by interaction of the previously identified elements and processes of combat.

To review, and perhaps expand a bit, the elements of combat are:

(1) Combat circumstances; initial objectives and missions (both sides)

(2) Natural and man-made environments in the area of operations

(3) Human resources, numbers and characteristics

(4) Material Resources,* numbers and characteristics

(5) Organization and structure of opposing forces

(6) Tactics, doctrine and operational concepts.

The processes of combat are:

(1) Attrition

(2) Movement

(3) Command, control, communications, and intelligence (C^3I)

(4) Combat support

(5) Combat service support.

In the traditional mathematical modeling of combat, one essentially puts the combat elements (as inputs) into mathematical formulations of the combat processes, tied together by appropriate logic. The resultant outputs are, in effect, the outcomes of the encounter between opposing

* All of the equipment and devices for the waging and the support of war.

forces. In this context, and as noted earlier, the combat elements are essentially the independent variables in the procedure (although not necessarily independent of each other) and the outputs or outcomes are the dependent variables. Furthermore, there are some gymnastics involved in reducing some of the rather broad considerations listed as combat elements to input variables that can be treated as "measurables." The connection is often more implicit than explicit. In a similar fashion, the quantitative or measurable outputs resulting from these mathematical operations may be expanded implicitly into broader interpretations of engagement outcome.

Perhaps the simplest graphical portrayal of combat is from Low [1]* Page xv and shown in Figure 1. The accompanying quotation from [1] is:

> "---Simply stated, all combat involves the interaction between opposing forces, designated RED and BLUE. These forces are composed of <u>men</u> and <u>equipment</u>, are governed by <u>operating procedures</u> and involve some measure of <u>combat support</u>. Both forces function in an <u>operational environment</u>, which is composed of natural factors such as weather and terrain. The interaction between RED and BLUE results in a <u>combat operations outcome</u>, which can be measured in a variety of ways---."

Sykes [2] gives additional substance to the "bare bones" concept of Figure 1 in the following excerpt.

> "---The interaction between RED and BLUE both affects, and is affected by, factors such as:
>
> <u>Command and Control</u>
>
> - Mission
> - Composition of force
> - Supporting units (artillery, aviation)
> - Battle Plan
> - Time of Battle
> - Posture (hasty defense, etc.)
>
> <u>Logistics</u>
>
> - Resupply
> - Transportation
> - Medical

---

*References are listed at the end of the paper.

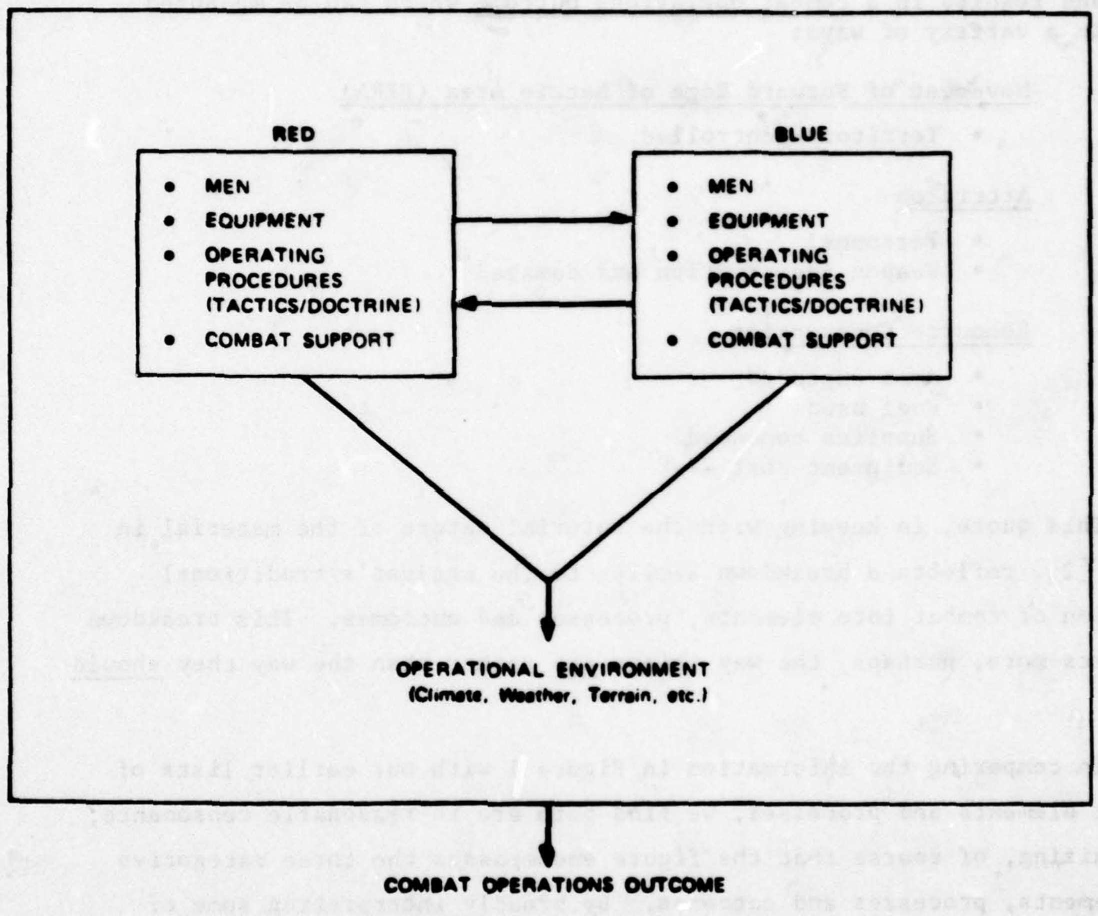

FIGURE 1 A CONCEPT OF COMBAT

- Equipment repair
- Construction (roads, bridges, etc.)

Attrition

- Weapon/Target characteristics (air-to-aur, air-to-ground, ground-to-ground
- Munition characteristics (e.g., precision-guided or free-flight, fragmenting or solid shot)
- Engagement characteristics (visibility, movement, range, terrain, etc.)

and results in a combat operations outcome which can be measured in a variety of ways:

Movement of Forward Edge of Battle Area (FERA)

- Territory-controlled

Attrition

- Personnel
- Weapon (destruction and damage)

Resource Consumption

- Ammo expended
- Fuel used
- Supplies consumed
- Equipment cost ---"

This quote, in keeping with the tutorial nature of the material in Sykes [2], reflects a breakdown similar to the analyst's traditional division of combat into elements, processes and outcomes. This breakdown reflects more, perhaps, the way things are rather than the way they should be.

In comparing the information in Figure 1 with our earlier lists of combat elements and processes, we find both are in reasonable consonance, recognizing, of course that the figure encompasses the three categories of elements, processes and outcomes. By broadly interpreting some of the factors in Figure 1, for example, "Operating Procedures" to include (5) and (6) under the elements of combat and (3) under combat processes, and "Combat Support" to include both (4) and (5) under combat processes, we find the acceptable agreement between the figure and the listings. It should further be noted that the parallel left-to-right and right-to-left arrows between RED and BLUE in Figure 1 represent attrition and movement

interactions (processes) between forces and that a larger block surrounding the figure could well represent (1) under combat elements.

Figure 2 intends to expand upon and to structure further the concept advanced in Figure 1 as well as to represent more explicitly the relationships among elements, processes, and outcomes. The type of warfare selected for purposes of illustration is ground warfare, involving combined arms operations, since this is generally conceded the most complex of all the forms of warfare that employ general purpose forces.

Figure 2 treats the phenomenon of combat so that it reflects the viewpoint of a systems analyst. The structure of the combat process in its entirety, as presented, is completely based on empiricism; that is, our observations of and experience with armed conflict as it has occurred countless times since the dawn of recorded history. While the figure does explicitly identify "modern" concepts like command and control and combat intelligence, these processes have existed at least vestigially, perhaps, throughout the entire history of warfare. It is only recently that some of them have been singled out as deserving special designation and recognition. It is of utmost importance, however, that the phenomenological "model" of Figure 2 not be limited in applicability and utility, because the viewer happens to be a social scientist, a mathematician, or a physicist/engineer. In spelling out how combat, as a set of fairly distinct entities, unfolds and how these entities interact with one another, the model should constitute a valid structural representation of what has happened repeatedly on the battlefields of the "real world" (and what is likely to happen in the future) quite irrespective of the disciplinary backgrounds of the viewers of the model.

Referring to Figure 2, we might start with the block labeled "Combat Forces" in which there appears a breakdown of land combat forces into a series of man/machine systems. Each of these systems (in the hands of a "typical" operator) has inherent performance characteristics and capabilities that are measurable in an engineering, laboratory, or proving ground sense. These characteristics are related to, but are not of themselves, true measures of effectiveness. Important in distinguishing the

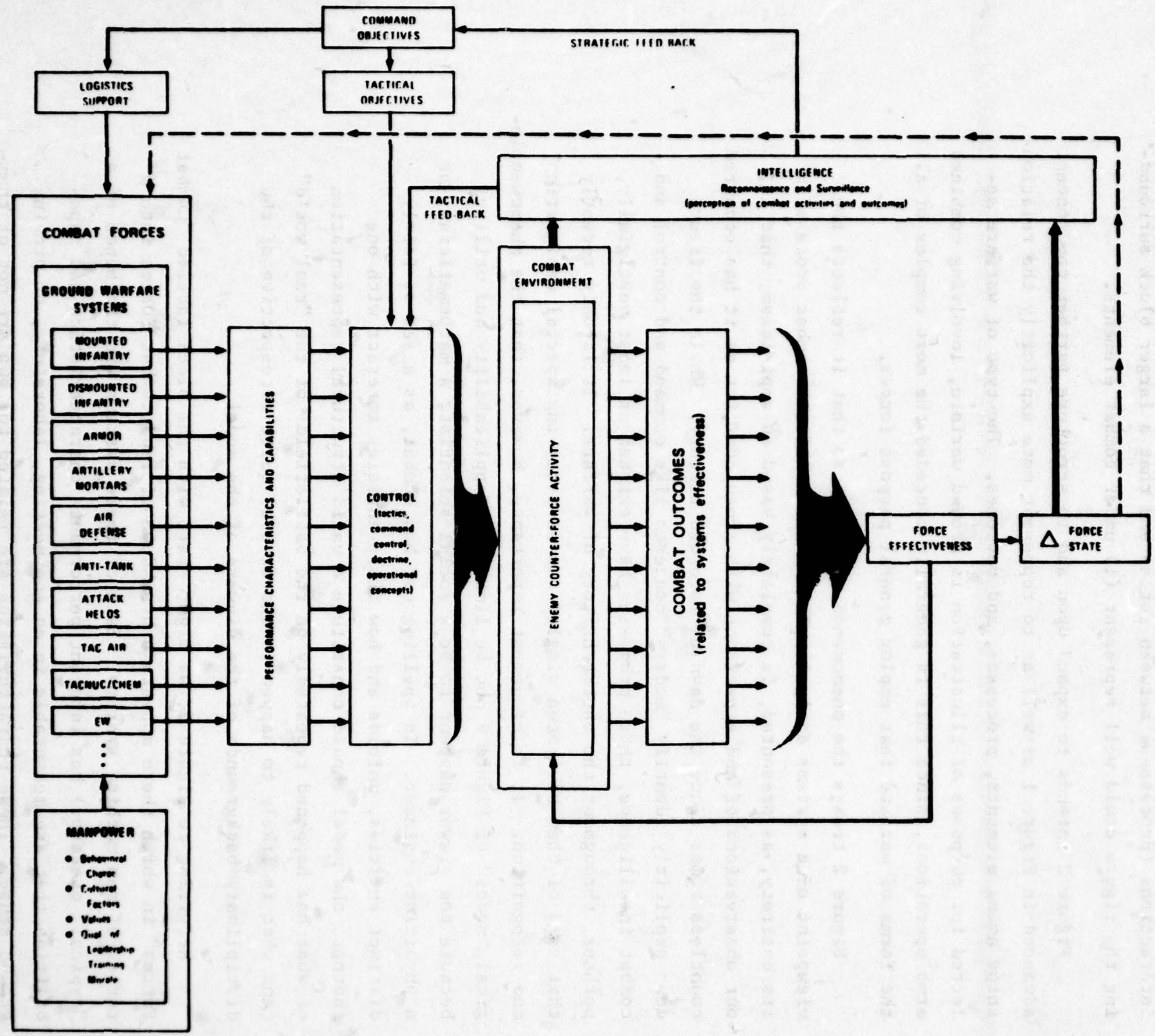

FIGURE 2 ANALYTICAL ELEMENTS OF GROUND COMBAT

difference between characteristics and MOE's is that in the definition of the former there is little or no dependency on the system mission and the threat which might confront the system; whereas in the definition of the dependency on mission and threat is fundamental. Examples of characteristics might be the steady rate-of-fire of an automatic weapon in an "auto-fire" mode or the rate-of-climb, maximum speed, or minimum turning radius of a fighter aircraft. While these characteristics provide some indication in a peripheral way of how well the system might perform in combat against an enemy, they do not directly provide an answer to that particular question.

As shown in Figure 2, the combat forces are influenced by a set of human factors and behavioral variables which are a very important, yet an oft-neglected (by analysts), part of the man/machine complex. These forces are supported by a logistics and supply system that provides them with manpower, food, fuel, ammunition, replacement equipment, construction, repair facilities, and spares. The force configuration is dictated by battle objectives ("Command Objectives" in Figure 2) and, based on these objectives, the capabilities of the men and equipment within the force are "controlled" and molded so they yield an appropriate vector of total combat power that can be directed against the enemy. This command/control function should recognize and attempt to capitalize on the synergistic effects of several or all of the ground warfare systems operating in a mutually supportive role against an enemy. Thus, in effect, will the employment tactics for the man/machine systems within the force be defined.

The concept of a measure of effectiveness for each and every system in the friendly force emerges from the combined interaction of these systems with the enemy forces in the battlefield environment. These measures are related to and in fact in certain instances are synonymous with combat outcomes at the systems level. Interaction alluded to generally take the form of attrition and movement or both. The individual effectiveness contributions for all systems theoretically combine in some manner to produce an overall measure of effectiveness for the friendly force(s). This measure encompasses the effects of weapon system

combat performance in relation to those of specific enemy units in a specific geographical and climatological environment, the behavioral characteristics of the human beings involved in the conflict, the differences in command objectives and in the nature and degree of control for both sides, and the ability of the logistics support system (which may well be subject to enemy attrition) to meet force demands. The force effectiveness is, in effect, an operator on the states of both enemy and friendly forces, influencing whatever changes in state that may occur ("Δ Force State" in Figure 2). From these changes in state one can determine whether the friendly force advances, retreats, or is in a stand-off condition with respect to the enemy force.

To complete this cursory description of a very complex process, Figure 2 contains an "Intelligence" block (incorporating the combat support processes of battlefield reconnaissance and surveillance) which is where potentially serious "noise" can be introduced into the system. This "noise" reflects the degree of difference between the perceptions and the realities of combat activities, outcomes and related factors. This difference almost always exists because of certain imperfections and delays in the gathering of information and the passing of it, and the execution of commands under battle conditions. The perceptions of what is occurring are fed back to the command structure and perhaps change the objectives and hence the level, composition, or employment (control) of forces ("strategic" feed-back). On the other hand, at a more local level on the battlefield, and with characteristically shorter time delays, these perceptions can influence changes in tactics (control) with the intent to alter the course of battle in a way favorable to the friendly forces ("tactical" feed-back). In association with the feedback loops and control block of Figure 2 there is implied an appropriate netting of communications.

From the foregoing, it should be clear that there exists an analytical flow diagram for the enemy forces that is identical to the one shown in Figure 2 for the friendly forces along the lines of Figure 1. This would branch out from the block labeled "Enemy Counter-Force Activity" in

much the same way that Figure 2 is oriented about the friendly "forces" block, but has been omitted for reasons of clarity. The entire process is a dynamic one and the existence of two such dynamic, symmetrical flow paths of information and activity for friend and foe portrays rather graphically the complex, two-sided nature of armed conflict.

The foregoing is an attempt to reconcile the analytical with the historical/judgmental points of view in studying the phenomenon of combat. We are addressing what is, in essence, a socio-technological system, where, traditionally, the analytical emphasis has been placed almost entirely on the "technological" (because it is relatively easy to deal with) and not on the "socio" (because it is relatively difficult). Even though Figure 2 localizes manpower characteristics within the "Combat Forces" block, it is easy to appreciate the strong influence these characteristics exert on the command and control and combat support processes. Ironically, there is strong evidence in the work of T. N. Du Puy [3] suggesting that in this system, the social/behavioral aspects of the problem may be just as, or more important than the technological aspects. One must always bear in mind, however, the fact that the two are strongly interrelated.

While Figure 2 attempts to identify all of the major factors and their interactions that influence the outcome in combat, we do not know which of these, under what particular set of conditions, act as drivers. Were this known, perhaps a vast simplification of the dynamic, looping structure described in this paper could be achieved. Be that as it may, it is the identification of the driving elements and processes that are fundamental to the development of a theory of combat.

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APPENDIX C:

APPROXIMATING A THEORY OF COMBAT

by

Reiner K. Huber*

1. Introduction

A theory may be defined as a system of scientific laws which conceptually reconstruct objective patterns on a subject (see Bunge [1], p. 27).

The process through which scientific laws are won is referred to as the Scientific Method. Figure 1 attempts a schematic *reconstruction* of that process. It initiates from a problem pertaining to questions not answered by the body of available knowledge on a subject. To answer these questions hypotheses are derived and their implications, i.e. testable consequences, are deduced. In order to verify the hypotheses, their implications are compared to empirical evidence obtained from experiments or tests. If there is agreement, i.e. the same conclusions are reached by both, the hypotheses and the empirical evidence, then we have a confirmed hypothesis or a scientific law. It follows that the verification of the deductively derived hypotheses with empirical observations of combat is prerequisite to eventually arriving at a viable Theory of Combat.

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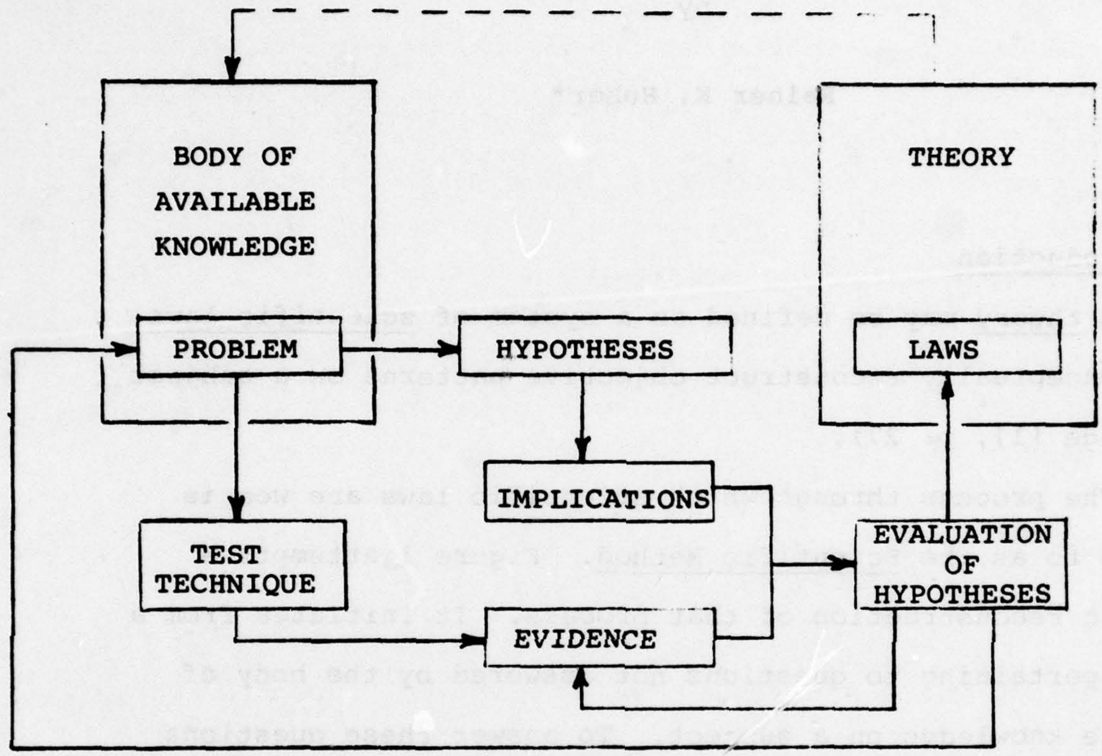

FIGURE 1.

The Scientific Method

2. The Verification Dilemma

Thus, the only rigorous technique to test the truth of combat hypotheses is to observe and measure events in actual combat[1]. Needless to say, the organization of such experiments is quite difficult and, in most instances, impossible. There only remains to extract the empirical evidence from records of historical battles. However, a viable statistical analysis of historical battle data is not readily accomplished, since historical records are rarely adequate in this respect (see R. O. Goad [4] and Schäfer [5]). Besides, the nature of most historical information is such that it may only confirm rather aggregated combat hypotheses (see Taylor [6]). Also, agreement as to the deductions from the hypotheses and the historical evidence confirms the respective hypotheses only insofar as they represent true models of combat under conditions as they prevailed at the respective historical period. Their relevance to future combat is by no means confirmed. With combat being a social rather than a physical phenomenon, the environmental dynamics prohibit a rigorous verification as in the physical sciences.

Thus, while the explanatory qualities of combat hypotheses and models may be verified, at least in principle, their predictive qualities may not. This poses a dilemma since the model deductions which are of interest to the military planner and commander refer

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1) World War II operations research was indeed characterized by drawing inferences regarding future military operations from the data gathered during the ongoing military operations (see e.g. Waddington [2], and Morse and Kimball [3]).

to things that are likely to happen in the future if particular courses of action or policies were pursued. The only way to alleviate this dilemma somewhat is to create an "ersatz" history by anticipating future combat through simulation experiments. Of course, such experiments are tests in a very limited sense because simulations are based on models[2], their results ultimately being but logical deductions from the employed models. But one might approach verification if simulation results cannot be falsified in historical settings.

3. The Concept of Falsification to Approximate a Theory of Combat

In our context, falsification is considered to prove that the simulation results could not have occurred in the historical setting of the simulation, or rather, that the historical battle could not have developed as the simulated battle did. Thus, a negative falsification does not require that the simulations reproduce the historical battle[3]. Positive falsification

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[2] With respect to combat simulation we distinguish three basic classes of models: (1) physical, (2) formal, and (3) hybrid models. Two-sided combat simulations employ either formal models (e.g. in simulation games; see Huber [7]) or a combination of physical and formal models, i.e. hybrid models (e.g. in interactive war games, field experiments, and military exercises; see [7] and [8]).

[3] It is apparently little understood that a (highly unlikely) reproduction of a historical battle event sequence by a simulation is no proof as to the "truth" of the underlying models. Due to the random nature of many events influencing combat, the course of a historical battle is rather unique and hardly reproducible if the same battle could be fought over again. Just as one run of a simulation model is of little value with respect to a prediction of battle outcome conditions, so is the historical battle. Therefore, the attempt to derive, from historical data, deterministic battle outcome prediction models or to calibrate or tune deterministic models such that they reproduce history appears to be of little value.

needs to prove that the course of the historical battle is not an element of the set of possible outcomes within the significance bounds of the simulation.

Thus, the concept of falsification implies that a deductively derived combat hypothesis may be considered viable as long as historical research does not provide statistically significant evidence for its rejection. While such <u>negative</u> *<u>falsifications</u>* are still short of a rigorous verification in the sense of the physical sciences, their repeated occurrence throughout a series of "historical tests" may nevertheless be considered as to approach verification of the respective hypotheses and thus resemble a reasonable approximation to "laws of combat" and eventually a theory of combat. From this we conclude that as a prerequisite to a viable theory of combat (being a set of "quasi-verified" hypotheses on military combat) we need to

(1) redefine the role of historical analyses and the historians' mode of operation so that statistically useful data are extracted from historical records permitting statistically significant falsification attempts (see e.g. McQuie [9]);

(2) design and operationalize a consistent and comprehensive methodological approach to combat simulation that allows us to systematically develop quasi-empirical data and insights on combat processes (see Huber [7]);

(3) organize a historical research program which extracts data (a) on the scenarios of historical battles as inputs to subsequent simulations of these battles and (b) on the testable consequences or hypothetical implications forwarded by combat simulations;

(4) develop the statistical and judgmental techniques which facilitate the historians' interpretation of simulation results in the light of the historical data with a view to the falsification of the simulations.

Whether such an effort is feasible and whether the underlying approach is viable needs further debate. However, its realization would support and extend Bonder's recommendations [10] insofar as it (a) requires extensive parametric analyses; (b) involves an intimate cooperation between military experts, historians, and systems analysts; (c) applies systems analysis as a research and learning vehicle rather than an instrument for advocacy (see [7,10]); (d) would contribute to the long range evolution of "standard models" by eventually providing an acceptable theoretical basis; (e) would help to reinstate the application of the principles of the scientific method in the field of military affairs thus contributing to the evolution of a true unified "military science" to replace today's misconceptions about military systems analysis set apart as a "scientific" tool to support (and frequently antagonize) an "artistic" military judgment.

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APPENDIX D

A REVIEW OF SOME PREVIOUS ATTEMPTS TO ESTABLISH A THEORY OF COMBAT

by

James G. Taylor*

1.0. Introduction

This paper is a companion paper to one on the conceptual bases for the establishment of a scientific theory of combat (see Huber [1]). It briefly reviews previous efforts at establishing a theory of combat. This is a working paper designed to stimulate discussion and further interchange among interested parties. The author would appreciate any and all communications on conceptual flaws, significant omissions, further references, etc.

2.0. Some Early Thoughts on Developing a Theory of Combat

The only attempt (known to this author) that has appeared (and at a very early date) to discuss an "adequate theory of combat" is H. K. Weiss's pioneering piece of work "Requirements for a Theory of Combat" [2]. Although our thinking has evolved quite a bit since this report's appearance in 1953, it is still worthwhile reading today (especially concerning command and control and behavioral

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aspects). Weiss's report is significant because it was a careful, reflective piece of work which first stressed the importance of empirical investigations on combat models and anticipated model-verification efforts carried out later by Weiss, Helmbold, and others (see Appendix for corresponding references).

Weiss's paper contains the germs of many ideas that have assumed great significance today. He stressed the importance of the verification of combat models against historical data ("actual combat records") and the use of simulated combat data (i.e. those that come from laboratory tests and field experiments) as model inputs. Weiss noted [2, p. 25] that data on the performance of system elements was "becoming available at a rapid rate." Weiss also presented a classification scheme for (independent) variables [i.e. those relating to (1) weapons, (2) users, (3) terrain, (4) targets, and (5) the enemy] (cf. Hayward [3] and also COL T. N. Dupuy (USA, ret.) of HERO [4]) and stressed the importance of behavioral aspects (e.g. "freshness" of forces). This report is also notable for its suggested enrichments in Lanchester's original work [5], some initial thoughts on a theory of morale, and discussion of the requirements for a theory of communications, which Weiss envisioned as a key element in any theory of combat.

3.0. Development of the Laws of Combat

In this section we will briefly review the conceptual basis for developing a scientific theory of combat, before we discuss what attempts have been made to establish such a historically-based theory. The latter evaluative step entails discussion of the sources,

nature, and availability of combat data and the modelling of combat operations.

3.1. Conceptual Basis

Here we take a theory of combat to mean an organization of the laws of combat. A law, in turn, is a confirmed hypothesis, i.e. a hypothesis that has been "confirmed" (or, more precisely, the truth of which has not been contradicted) by the available empirical evidence (see Huber [1] for a more complete discussion). Within the context of military operations research (OR), such a hypothesis to be confirmed may be considered to be quantitatively expressed as a model. Thus, a major step towards a theory of combat is the development of scientific laws for military combat. Such laws would then be the basis[1)] for developing models of combat processes for defense-planning purposes.

Combat models are widely used by DoD as decision aids in defense planning (see Taylor [8, pp. 774-776] for further details). Does such a model (necessarily an abstraction) agree (or, at least, not disagree) with the realities of the physical world (either now or in a possible future)? Thus, the combat scientist is faced with the very practical problem of verifying the combat model, perhaps

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1) Today such combat models and simulations are by and large based on unconfirmed hypotheses. In fact, documentation (at least in the recent past) of models used by DoD has been so bad (e.g. see Shubik and Brewer [6]) that many important models either are not documented or (if they have been documented) their conceptual bases are not explained (although detailed program listings may be provided). What is needed is an organized and nontechnical explanation of a combat model's conceptual bases, with technical back-up being provided in a selective (and possibly hierarchical) fashion (e.g. see Shupack [7]).

with respect to future possible circumstances and not the realities of today. In general, the problem of verifying models of man/machine systems is quite difficult (e.g. see Naylor and Finger [9] or Van Horn [10], and combat models present a number of special subtleties (see also Huber [1]), although the process of model verification frequently appears to the uninitiated to be straightforward. We will now discuss a few of these subtle points, but much more careful reflective discussion is needed on this difficult subject.

Special subtleties present in the scientific verification of combat models are as follows:

(1) principle of uniformitarianism does not hold,

(2) systems are only partially observable,

(3) conceptual basis of knowledge is more like that in the social sciences than that in the physical sciences.

The physical sciences are essentially based on the principle of uniformitarianism, which holds that physical and biological processes, conditions, and operations do not change over time (i.e. uniformity over time). For example, in geology the doctrine of uniformitarianism holds that the present is the key to the past [11]. This principle, of course, does not hold for planning models of new future environments (e.g. see Howland [12]). Thus, the combat modeller faces a special problem (which has gone largely unnoticed) in verifying his models: the empirical data base for the testing of such a model is from the real world (past), whereas

the prediction from the model is for the real world (future). What is meant by the verification of such a planning model is in need of critical examination. Additionally, in contrast to the modelling of purely physical systems, combat models involve (1) hardware (e.g. weapons) and physical processes, (2) people, and (3) or organizational structures. Although human behavior in combat may not change appreciably over time, weapons (i.e. hardware) and organizational structures have and will continue to change appreciably. Thus, the principle of uniformitarianism does not hold for combat analysis, and we cannot use the past by itself to predict the future for combat operations.

Furthermore, since wars are fought for reasons other than just for collecting combat data, even our knowledge as to what has occurred in past combat is imperfect and incomplete. One might even say in technical jargon that military systems in combat are only "partially observable." Finally, since combat models resemble social-science models more than physical-science ones, the standards of knowledge about combat should be more like those of the social sciences than those of the physical sciences. Unfortunately, this has caused difficulties, since the backgrounds of most military OR workers are most closely related to the latter field (i.e. the physical sciences). It appears that epistemological concepts from the social sciences should be quite useful and possibilities in this direction should be further explored in the future.

3.2. Sources, Nature, and Availability of Combat Data

One should distinguish between two types of combat data:

(1) real combat data,

(2) simulated combat data (i.e. data generated in a simulated combat environment by field experiments, field exercises, war games, machine simulations, etc.).

The two basic primary sources of real combat data are (see McQuie et al. [13] or McQuie [14] for further details):

(1) archives,

(2) official military histories.

Unfortunately, quantitative data that is needed from these primary sources for verification of mathematical models of combat is not readily available: the extraction of such quantitative data from archives requires great investment in manpower of a highly specialized nature (one essentially needs a military historian), while the official histories (at least those for the U.S. Army) are purely narrative and do not contain tables, graphs, or appendices with data [14]. COL T. N. Dupuy (USA, ret.) of HERO is undoubtedly at least as knowledgeable as anyone in the world on such data and will hopefully answer any questions that the author cannot. Moreover, HERO has provided (from winter 1975 until spring 1978) a "Combat Data Subscription Service," whose volumes contain quantitative data (laboriously) extracted from archives[2]. Finally, secondary sources

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[2] Unfortunately, this valuable service had to be terminated after two volumes of (quarterly) publication apparently due to lack of support.

of real combat data are discussed in many of the papers mentioned in the Appendix.

After a thorough study of the sources, nature, and availability of real combat data, McQuie et al. [13] concluded that for the purposes of statistical analysis, the data available on World War II and Korea are "inadequate, incomplete, and probably biased." Incompleteness is a particular problem, with data measured for one engagement frequently not available for others [13]. Moreover, the available real combat data is essentially of an aggregated (as opposed to detailed) nature, i.e. "bean counts" for the larger combat units (see McQuie et al. [13] or McQuie [14] for further details). In other words, the available historical records do not provide detailed combat data such as the positions of individual weapons, targets engaged, engagement conditions for individual target-firer combinations (including the number of rounds expended at each target), etc. Thus, <u>the available real combat data does not support verification of detailed combat models, but it only supports such investigations of relatively simple aggregated large-unit models</u> (see Taylor [15] for a discussion of detailed versus aggregated combat-attrition models).

However, using simulated combat data, one can in principle verify either detailed small-unit (or even many-on-many) models or the submodels used in such models. There have apparently been some efforts along these lines (e.g. by the U.S. Army's Combat Developments Experimentation Command (CDEC)) but information dissemination about them is poor to nonexistent. The author can supply no specific

references outside of mentioning the recent TETAM (Tactical Effectiveness of Antitank Missiles) study[3] by the U.S. Army.

3.3. Verification of Combat Models

There have been some (but surprisingly few) attempts to verify combat models. To place this work in proper perspective, it is convenient to conceptually factor the overall combat process into the following four components (see Huber, Low, and Taylor [16] for further details):

(1) attrition,

(2) movement,

(3) C^3I (command, control, communications, and intelligence),

(4) support.

Verification efforts have concentrated on the first of these four processes, and for present purposes so will we. We may also consider that there are different organizational levels at which combat can be represented. One example of such a set of levels is as follows:

(1) force-on-force { (a) large scale, (b) small scale,

(2) many-on-many,

(3) few-on-few,

(4) one-on-one,

(5) engineering design.

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3) LTC Richard S. Miller, USA, of the Naval Postgraduate School can elaborate upon particulars here.

The available (real) combat data[4] is only on Level 1 of the above classification scheme, i.e. force-on-force operations, and then apparently predominantly for large-scale operations. Generally speaking, one can develop both detailed and also aggregated models of combat processes at each of these five levels (cf. Taylor [15]). Model verification efforts, moreover, have apparently considered only the attrition process[5] for such large-scale force-on-force combat. Furthermore, there are only two general approaches for verifying such large-scale attrition models:

(A1) "replay" some particular historical battle(s) to see whether or not the model satisfactorily "reproduces" the historical outcome(s),

and (A2) find regularities or "patterns" in historical battle data, and then determine whether or not the model exhibits a similar "pattern."

The first approach has generally involved large-scale <u>detailed</u> models and large-scale <u>aggregated</u> data (e.g. see Fain and Wilson [18]). One can raise serious objections about the

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4) Simulated combat data of one form or another exists on essentially all levels, particularly the lower levels (i.e. few-on-few and below).

5) Bonder [17] has considered models of different combat processes at three different levels: (1) individual firer against a passive target, (2) small-unit combat (battalion and below), and (3) large-scale combat. He has discussed the verification of models at these three system levels. Based on our knowledge of the available combat data, such verification can only pertain to simulated (and <u>not</u> real) combat data (here some type of field experimentation), but this fact is not explicitly pointed out to the reader. No references are given by Bonder [17].

scientific validity of this approach, although it is beyond the scope of this paper to further discuss this point. The second approach has generally involved large-scale aggregated models and large-scale aggregated data and has by and large considered the classic constant-coefficient Lanchester-type equations for modern warfare (e.g. see Taylor [19], [20]), with mixed results being reported (see the Appendix for further details). To this author, the general consensus seems to be that such a simple functional form is not violently contradicted by the available combat data but that the consequent model predictions are statistically too inaccurate for practical use [21] (cf. McQuie et al. [13, p. 93]). A careful review and integration of such past work is lacking and seems to be in order before plowing new ground.

The Appendix to this paper contains a brief discussion of most of such empirical verification efforts that are contained in unclassified sources and are known to this author (see also Boulton et al. [22]). Most of these investigations have used only (very aggregated) combat data from secondary sources. There are also undoubtedly some further investigations that are "buried in" classified documents (e.g. see Fain and Wilson [18]). Such investigations should be cataloged and organized for DoD analysts.

4.0. Prospects for Future Work

It appears to this author that it is both feasible and also highly desirable to improve DoD combat-modelling efforts[6)] by

6) Considering that upwards of $30 million is spent on just the development of new operational combat models each year (see Shubik and Brewer [6, p. 12]), it is curious that little basic research on any theory of combat, combat-modelling methodologies, or combat models in general is apparently being undertaken by the U.S. Army Research Office (ARO), the Office of Naval Research (ONR), or the U.S. Air Force Office of Scientific Research (AFOSR).

further examining the empirical validity of combat models. There are a number of rather subtle issues that need articulation (and possibly even resolution) before such work can be seriously undertaken, however. For example, the available data base will probably support the verification of only simple aggregated models of large-scale combat, whereas the trend is towards the use of more and more detailed models. The full potentialities of available data sources should be exploited to extend and refine the real-combat data base. Along these lines, the work of COL T. N. Depuy (USA, ret.) and HERO is to be commended. Much more quantitative combat data should be generated from archival and military-history sources for the combat-modelling community to use.

A thorough review and integration of past efforts should be the initial part of any new work, and the conceptual issues raised by such review of past work should then at least be discussed before any new analysis is undertaken. In all cases, such work should (1) be done in a careful, reflective atmosphere, and (2) be given wide dissemination (e.g. report placed in DDC) to all interested parties. Coordinated efforts seem to be required for any real progress, with "critical mass" and "sustained effort" highly desirable (if not essential).

Thus, the author would like to end this paper with the following conclusions and rhetorical questions:

(1) empirical verification of combat models should be vigorously pursued;

(2) the data base on real combat should be extended and refined by further historical research on archives

from past combat; such work should be closely coordinated with (and possibly directed by) combat-modelling efforts (including model verification);

(3) the entire topic of verification of combat models needs further discussion and articulation;

(4) it seems appropriate to assess where we have been (i.e. exactly what previous work has shown) before striking out in new directions;

(5) important outstanding questions are the following:

(A) How should simulated combat data be used in the model verification process?

(B) How can the current generation of large-scale detailed combat models (e.g. see [23]) be evaluated in terms of the available historical data?

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APPENDIX: Historical Validation of Attrition Models

What confidence do we have that our models can actually predict what might happen in future possible combat? The simple fact is that if we are honest, there are some severe limitations on the current state-of-the-art as far as how literally we should believe model outputs. The main problem is that the nature and quality of the available combat data is so extremely poor[1] that we have no reliable "bench mark" against which to "calibrate" our combat models. Compared with the physical sciences, there is an almost complete lack of historical combat data. Although future combat may be quite unlike that of the past due to the introduction of new technologies and weaponry, it does seem desirable to (in some sense) calibrate our models with past operations. Time prohibits the in depth discussion of this important topic, but we will now briefly review what little has been done.

A number of studies (see Table I) have considered verification[2] of very simple Lanchester-type models, i.e. Lanchester's

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[1] See Helmbold [8] and McQuie [16] for discussions of the limited availability of historical combat data. Helmbold discusses the nature of data available from secondary sources (e.g. history books), while McQuie discusses the nature of data available from primary sources (e.g. unit reports and official military histories). Additionally, McQuie discusses the shortcomings of the historical combat data that does exist. He provides an outstanding discussion of the nature, availability, and quality of historical data.

[2] We are here using the words "verification" and "validation" interchangeably. Many authors distinguish between the verification and the validation of a model, but there is apparently no consistent use of these terms in the literature (see, for example, Morris [17], Bonder [1, pp. 68-70], Van Horn [24], and Naylor and Finger [18]). For our present purposes, however, such a distinction does not seem warranted, especially since there is not consistent use of these terms in the literature.

TABLE I. Authors Who Have Investigated the Empirical Verification of Lanchester-Type Models of Warfare.

J. H. ENGEL (1954)

H. K. WEISS (1957, 1966)

R. L. HELMBOLD† (1961a, 1961b, 1964a, 1964b, 1969, 1971a, 1971b)

D. WILLARD (1962)

W. A. SCHMIEMAN (1967)

J. J. BUSSE (1971)

R. W. SAMZ (1972)

J. B. FAIN (1977)

†Here HELMBOLD (1961b) = the second paper published by Helmbold in 1961 (see list of references at the end of this appendix).

classic formulations[3] and simple variations thereof. In Table I we give the authors' names and publication date of every empirical-verification examination appearing in the open literature and known to the author. The exact reference to each piece of work may be obtained by consulting the list of references at the end of this appendix. All this work has considered secondary sources and combat data, i.e. data available from other sources such as history books. Usually considering only initial and final strengths in numbers, it has generated results that at best may be called inconclusive. This result is not too surprising, since "aggregated" forces were considered without any type of "scoring" (i.e. weighting) of the various different weapon-system types comprising the opposing heterogeneous forces.

Positive results (i.e. reports of theoretical consequences not at variance with the available combat data) have been reported by Engel [3], Weiss [25; 26], Helmbold [5-7; 9-11], Schmieman [21], Busse [2], and Samz [20]. For example, Weiss [25] reports that there is some justification for using Lanchester-type equations of

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3) See Lanchester [15]. More accessibly, these simple differential-equation combat models are given by, for example, equations (2.1) and (2.3) of Taylor [23].

modern warfare[4] "as a point of departure" in modelling combat. On the other hand, after a rather lengthy and comprehensive analysis, Willard [27, p. 4] concluded that his analysis did not justify the use of Lanchester's classic equations (see Footnote 3 again) for modelling large-scale combat. This conclusion is not at all surprising, since heterogeneous forces were aggregated on the basis of numbers alone without any "scoring" of the various different weapon-system types. Moreover, when such "scoring" is used, much more positive results have been reported (see Fain [4, pp. 38-39]).

At a conceptual level, Helmbold [10, pp. 1-3] has pointed out that there are only <u>two</u> general methods for verifying [or testing[5]] combat models:

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4) Here (as elsewhere in such verification work) constant attrition-rate coefficients were assumed. In this case, the equations in question are given by

$$dx/dt = -ay \qquad \text{and} \qquad dy/dt = -bx,$$

with initial conditions

$$x(0) = x_0 \qquad \text{and} \qquad y(0) = y_0,$$

where $x(t)$ and $y(t)$ denote the numbers of X and Y combatants, and a and b are constants that are today called Lanchester attrition-rate coefficients (see Taylor [22] for further details).

5) There are, of course, other positions that one can take concerning the verification of models (see, especially, Naylor and Finger [18]). In the main text we have presented the two that are most germane to combat models.

(M1) "replay" some historical battle(s) to see whether or not the model satisfactorily "reproduces" the historical outcome(s),

and (M2) find regularities or "patterns" in historical battle data, and then determine whether or not the model exhibits a similar "pattern."

The usual difficulty with the first method (M1) is that insufficient data is available on any one historical battle to carry out the proposed comparison (see Helmbold [10]; also McQuie [16]). Even when sufficient data is available, rather restrictive assumptions must be made about the conduct of battle, and critical appraisal of these assumptions leads one to raise serious objections about generalizations based on such an examination (see Helmbold [10, pp. 1-2] for further details). The work by Engel [3], Busse [2], and Samz [20] falls into this first category (M1), while that by Weiss [25; 26], Helmbold [5-11], and Schmieman [21] falls into the second category (M2). This second method (M2) is nothing more than the Scientific Method of verifying a model indirectly through checking testable consequences against observations, the so-called hypothetico-deductive method (see Morris [17, pp. 101-103]).

Engel's work [3] gets more attention from the uninitiated than it probably should. Its weakness is that he estimated parameters and also tested the model with the same set of data and forced a fit through the initial and final force levels for the battle of

Iwo Jima. In fact, all such attempts at model verification by method (M1), i.e., historical "replay," suffer from such deficiencies (see Helmbold [10, pp. 1-2] for a further discussion). On the other hand, Helmbold's work [5-11] has been much more comprehensive. He has sought to indirectly test Lanchester-type combat models against the available historical data by empirically examining the testable consequences of such models[6]. He has applied this approach not only to ground battles [5-7] but

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[6] Helmbold's basic idea was to find regularities or "patterns" in historical battle data and then to determine whether or not a given simple combat models (Helmbold took Lanchester's equations of modern warfare) exhibits a similar "pattern." From his historical data, Helmbold found that relative fire effectiveness a/b (i.e. the ratio of the fire effectiveness of an individual Y combatant to that of an individual X combatant) to be strongly correlated with the initial force ratio x_0/y_0. Helmbold's data base consisted of initial and final force levels for both sides for several hundred historical battles, with one side identified as the attacker (X) and the other (Y) as the defender. Assuming that the so-called square law held, Helmbold computed the initial force ratio x_0/y_0, survivor fractions x_f/x_0 and y_f/y_0, advantage paramenter $V = \ln \mu$ where $\mu = \{1 - (x_f/x_0)^2\}/\{1 - (y_f/y_0)^2\}$, activity ratio (in our terminology, relative fire effectiveness) a/b, and the "bitterness" parameter $\epsilon = \sqrt{ab}\, t_f$ for each of (all told for the three investigations [5-7]) several hundred battles. As indicated above, his idea was to collect a sizable body of data dealing with the historical battles, use this data to compute parameters (advantage, activity ratio, and bitterness) associated with each battle, and search the results for regularities.

also to air battles [10] and has reported positive results concerning the validity of Lanchester-type combat models. More recently, he [11] has examined the validity of "breakpoint-type" hypotheses and found that "the breakpoint hypothesis yields theoretical implications that are at variance with the available battle termination data in several essential respects."

On the other hand, T. N. Dupuy [12-14] has examined combat data from primary sources and has in some sense shown the validity of the firepower-score approach. His work apparently is the original empirical basis for both the ATLAS and also TBM (see [19]) casualty-rate curves. Subsequently, J. Fain [4] has analyzed HERO (Historical Evaluation and Research Organization) World War II data on 60 engagements in four major Italian campaigns and has reported positive results concerning the scientific validity of Lanchester-type models of warfare (particularly when a "scoring" system is used to aggregate the heterogeneous forces). She [4, p. 34] has emphasized that the HERO data (of which she examined only a small part) is the most nearly complete and accurate collection of combat data. Much more work should be done in this area. It is encouraging that today HERO offers a "combat data subscription service" and a journal entitled History, Numbers, and War.

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